Project No. 10-12

PROJECT REPORT

TECHNOLOGY DEMONSTRATION PROJECT

Application of fly ash, organic manure and mycorrhiza biofertilizer for improvement in tree plantation

Implemented by :

Tata Energy Research Institute
(TERI)

Partner institute & location

Indian Institute of Technology, New Delhi

For

Fly Ash Mission

Technology Information, Forecasting &
Assessment Council (TIFAC)
Department of Science & Technology
New Delhi

APRIL 2000

(Inside Coverpage)

Fly Ash Mission

Based on Techno Market Survey on fly ash generation and utilization by TIFAC during 1992 and detailed field work during 1993-94 and appreciating the overall concern for environment and the need for safe disposal & gainful utilization of fly ash, Fly Ash Mission was commissioned by Government of India during August 1994 with Department of Science & Technology (DST) as the Nodal Agency and Technology Information, Forecasting and Assessment Council (TIFAC) as the Implementing Agency.

The focus is on Technology Demonstration Projects for developing confidence in fly ash technologies towards large-scale adoption. 55 projects taken up with industry – R&D and academia consortia have shown encouraging results. Most of the projects have been completed, multiplier effects have started and other projects are heading towards meaningful completion. A judicious mix of the following Thrust Areas has been selected for concerted efforts.

Fly Ash Utilization	Safe Management	Facilitation
• Roads and embankments • Building components • Hydraulic structures • Agriculture related studies and applications • Underground mine fills	• Ash ponds and dams • Reclamation of ash ponds for human settlement	• Characterization of fly ash • Handling and transpiration • Research and development

The Thrust Area "Agriculture Related Studies and Applications" has 15 projects spread over 55 sites, covering different soil-crop combinations under different agro climatic conditions. These projects address to the cultivation of field crops, oilseeds, sugarcane; development of wasteland; plantation of forest trees and floriculture species; reclamation of user soil and also analysis of produce to study the impact of fly ash on nutritional quality of crop.

Encouraging results have been obtained from the projects under all Thrust Areas. The increasing response and participation has been observed from fly ash producers, R&D institutes, industries, academia and end users. Special groups for flyash management are being established by state governments.

The efforts of Fly Ash Mission towards large-scale utilization / safe disposal of fly ashes and catalyzing effort in the country are with the participation and close association of Ministry of Environment and Forest (MoEF), Ministry of Power (MOP), thermal power plants, R&D institutions, academia and industry. The efforts have increased the utilization from 3% in 1994 to 20% in 2001.

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Indian Institute of Technology, Delhi

Indian Institute of technology is one of the premier institutes established by the government of India to provide state of the art engineering education, research and technological management. The main focus of IIT is to carry out path breaking research and suggest means for mitigation of technological problems. Over the last 4-5 years IIT has undertaken a special drive to green up its 250-acre campus. IIT is also actively associated with FAM activities towards gainful utilisation/safe management of fly ash. A number of FAM projects, are being implemented by IIT including this project.

For further details, please contact Director, IIT, Delhi. Phone: 6867541; Fax: 6857659

About TERI

A dynamic and flexible organisation with a global vision and a local focus, TERI was established in 1974. While in the initial period the focus was mainly on documentation and information dissemination activities, research activities in the fields of energy, environment, and sustainable development were initiated towards the end of 1982. The genesis of these activities lay in TERI's firm belief that efficient utilisation of energy, sustainable use of natural resources, large-scale adoption of renewable energy technologies, and reduction of all forms of waste would move to the process of development towards the goal of sustainability.

Amongst the various activities, the Centre of Mycorrhizal Research (CMR) at TERI is doing research on the application of mycorrhizal biofertilizer to different plant species under field conditions and also on the abatement of environment pollution threat by fly ash overburdens. CMR has successfully demonstrated the reclamation of ash ponds under another project of Fly Ash Mission, TIFAC, DST on application of fly ash as a soil enricher using mycorrhizal organo-biofertilizer. This has been possible through vigorous screening of tree/plant species and mycorrhizal isolate combination, which are capable of growing in such hostile conditions.

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(Inside back page)

Fly Ash Mission Technology Demonstration projects undertaken in "Agriculture Related Studies & Applications" Thrust Area

Sl. No.	Project number and title	Implemented By
1.	10-01: Bulk Scale Utilisation of Fly Ash from Farakka STPP in Agriculture and for Reclamation Of Degraded Lands of Murshidabad District (West Bengal)	Central Fuel Research Institute, Dhanbad
2.	10-02: Bulk Utilisation of Coal Ash from Bakreswar Thermal Power Plant in Agriculture Land of Birbhum District (West Bengal)	Central Fuel Research Institute, Dhanbad
3.	10-03: Fly Ash Disposal and Utilisation in Agriculture Applications	Annamalai University
4.	10-04: Long Term Effect of Fly Ash on Soil Fertility and Crop Yield	Regional Research Laboratory, Bhopal
5.	10-05: Utilisation of Fly Ash in Agriculture	College of Agriculture, Raichur
6.	10-06: Use of Fly Ash for Enhancing Crop Production	Punjab Agriculture University, Ludhiana
7.	10-07: Utilisation of Fly Ash and Organic Waste in Restoration of Crop Land Ecosystem	Indian Institute of Technology, Kharagpur
8.	10-08: Utilisation of Fly Ash for Soil Amendment to Increase Forest Productivity	Thapar Centre for Industrial Research & Development, Patiala
9.	10-09: Application of Fly Ash as a Soil Enricher in Arid Lands using Mycorrihiza Bio-Fertiliser at Jaipur	Tata Energy Research Institute, New Delhi
10.	10-10: Reclaiming Ash Ponds by Means of Mycorrihizal Organo Bio-Fertilizer	Tata Energy Research Institute, New Delhi
11.	10-11: Use of Fly Ash as a Soil Reclaimant Alone or in Combination with Other Soil Reclaiming Agent	Indian Farmers Fertiliser Co-operative limited, Phulpur
12.	10-12: Application of Fly Ash, Organic Manure and Mycorrihiza Bio-Fertilizer for improvement in Tree Plantation at Delhi	Tata Energy Research Institute, New Delhi
13.	10-13: Effect of Fly Ash on Quality / Nutritional Aspects of Agriculture and Horticulture Produce	National Institute of Nutrition, Hyderabad
14.	10-14: Effect of Fly Ash (Angul) on Soil Fertility and Crop Yield	Regional Research Laboratory, Bhopal
15.	10-15: Bulk Utilisation of Fly Ash for Wasteland Development, at Sarni	Regional Research Laboratory, Bhopal

Implementing Agency: Tata Energy Research Institute
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At the outset, we thank Professor V S Raju, who was at the time, Director, IIT-Delhi and Dr Vimal Kumar, Mission Director, Fly Ash Mission for conceptualizing this project on the use of fly ash to augment forestry activities in the low fertility termite-affected sites on the IIT-Delhi campus.

The work conducted under this project was possible due to the continued support and co-operation of the Fly Ash Mission, TIFAC. Special thanks are due to Dr Vimal Kumar for his co-operation and encouragement. Thanks are also due to the staff of IIT Delhi for their kind support and especially for the help provided in maintaining the plantation on the IIT campus. The members of the monitoring committee made several useful suggestions during the course of work. All advice, help rendered by the members is duly acknowledged. Special thanks to Professor V Seshadri, Deputy Director (Admininstration) and Dr Girotra, IIT Delhi.

Thanks are due to Dr R K Pachauri, Director, TERI, for providing all necessary help and infrastructure. Thanks are also due to the task force and monitoring members to whom the project progress was presented from time to time and for the suggestions given during these meetings. The work would not have been possible without the continued support from colleagues who worked for this project at TERI and IIT.

Alok Adholeya

CONTENTS

CHAPTER		PARTICULARS	PAGE No.
		Executive summary	
Part I	**1.0**	**Introduction**	**1 – 2**
Part II	**2.0**	**Project profile/outline**	
		2.1 Introduction	
		2.2 Origin of proposal	**4**
		2.3 Objectives	**4**
		2.4 Site plan	**5**
		2.5 Work period	**5**
		2.6 Various activities	
		2.7 Work plan	**6**
		2.8 List of tree species	**6**
Part III	**3.0**	**Implementation**	
		3.1 Treatments	**7**
		3.2 Raising of plantlets	**8**
		3.3 Selection of tree species	**8**
		3.4 Transplantation	**8**
		3.5 Soil sampling and analysis	**9**
		3.6 Methods	**10**
	4.0	**Results and discussions**	**12**
		4.1 Survival and height of tree species	**15**
		4.2 Survival data	**15**
Part IV	**5.0**	**Conclusion**	**20**
Part V	**6.0**	**Suggested future plan of action**	**20**
Part VI	**7.0**	**Photographs**	**21**
Part VII	**8.0**	**References**	**26**
Part VIII	**9.0**	**Glossary / Abbreviation / Units**	**28**
		Annexure	

PART I

1.0 Introduction

Pulverized fuel ash generated by burning of pulverized / ground / crushed coal or lignite at modern time thermal power plants has been applied to agriculture applications by scientists. The advantages of applications of fly ash or pond ash in terms of improvement of soil properties and increase in yield have been published by large number of scientists in the country and abroad. Concerns have also been voiced about the plausible negative impact of use of pulverized fuel ash in agriculture due to presence of heavy/toxic elements and radioactive nucleides in fly ash. Its evident from the analysis of Indian fly ashes that the presence of heavy/toxic elements and radio-nucleides in it are at trace level that may not have significant impact. The literature voicing concern about the plausible negative impacts of fly ash have generally not provided the information about experiment design as well as analytical results.

Fly Ash Mission conceived the project implementation design and strategy keeping the above in view. The **prime objective** of Technology Demonstration Projects under the Thrust Area "Agriculture Related Studies and Applications" **is** taken as:
"To develop the empirical evidence / data from systematically and scientifically implemented field projects for the beneficial / undesired effects of application of fly ash / pond ash to agriculture and forestry."

The positive impacts that have been studied are with respect to yield plant growth related parameters and improvement in physical health of soil. The likely undesired impacts taken up for study are: effect of heavy and toxic elements and radio-nucleides content of fly ash on soil, ground water quality, up take of these elements by plants parts & produce.

Technology Demonstration Projects have been taken up with varying soil crop combination under different agro- climatic conditions. The projects include cultivation of cereals, pulses, oil seeds, vegetables, sugarcane, cotton; plantation of forest trees and floriculture species; reclamation of usar soil; development of wasteland an analysis of nutritional value of produce grown on ash treated soils, etc.

The present project is a part of this initiative where efforts are made to demonstrat how fly ash could be useful in plantations and soil improvement. The biologic intervention such as organic manure and mycorrhizae were also incorporated i order to demonstrate that benefits can be further enhanced with such usef combinations in wastelands/soils of low fertility. The results obtained have show that various aspects can effectively be addressed and eventually a successf greening can be achieved using fly ash in degraded soils.

PART II

2.0 Project profile

2.1 INTRODUCTION

Coal contributes to about 40% of electricity generation in the world and a typical modern coal fired station in India burns 0.7 T/MW/hr of coal, consequently generating ash @ 0.28 T/MW/hr.

The use/disposal of ash in an environmentally safe manner is a critical issue in India. In 2000, about 95 million tonne of ash was generated out of which about 15 million tonne (16%) was utilized. Presently, majority of the coal ash generated at thermal power stations is being handled in wet form and disposed off in ash ponds. Ash collected at various points is transported to disposal areas by wet disposal or dry disposal. The wet disposal system requires large amount of land, about 1½ acre per MW of installed capacity, and a large capital investment. Besides the land requirement the potential threat of air pollution in the form of fugitive dust and water pollution - both surface and ground water deserve attention while dealing with ash ponds of thermal power plants.

The potential for utilization of fly ash in the agriculture and in reclamation of wasteland in India is significant. Fly ash has been found to have several nutrients that assist in plant growth. Of the 393 million hectares of total available land, about 200 million hectares is non-cultivable in India. This non-cultivable land may be improved by the use of fly ash.

Overall activities related to reclamation of ash ponds have innumerable advantages such as prevention of fugitive dust from ash ponds, checking soil erosion, stabilizing the surface areas of ash, preventing the potential ground water contamination and finally, adding very vital vegetation cover, in the long run. Reclamation activities not only facilitate performance and growth characteristics of species to build a database for future reference but also, provides commercial options for better utilization of these areas.

In the present project, four treatments were used in order to study the impact of fly ash and useful associated microorganism such as mycorrhiza for improved plant survival and growth. The treatment includes farm yard manure (FYM), fly ash and mycorrhiza amendment, farm yard manure and fly ash amendment, farm yard manure and mycorrhiza amendment and local farm yard manure only which was the ongoing practice at project site. These treatments were distributed into four sites having different characteristics. The parameters, which were considered to study, were, survival after transplantation, growth and soil improvement. Since there were many stress factors, besides many physical constraints, both had compounding effect on survival losses. A number of beating up operations were carried out in order to achieve hundred per cent survival. The project in its first phase achieved the set- forth objectives.

2.2 Origin of the Proposal

IIT, Delhi has taken a special drive to green up its campus since last 4-5 years ago. About 2000-3000 plants are planted every year utilizing the manual management practices. The poor growth of plants in the infertile soil of IIT campus drew the attention of its administration of IIT to means of enhancing the growth of plants in such an environment. Fly Ash Mission was approached to demonstrate TERI's technology for the use of fly ash in enhancing the growth of plants in poor soil.

2.3 Objectives

The project aims to demonstrate the use of fly ash as a soil enricher along with mycorrhizal fungi using selected tree species at a degraded site in IIT, Delhi campus.

The objectives include:

i) Demonstrating use of fly ash as a soil enricher resulting in betterment of soil quality.

ii) Enhancing establishment and growth of plants by increasing nutrient uptake using mycorrhiza.

2.4 Site plan (location and layout): See annexure 1 to 4

2.5 Work period: November 1997 - October 1999

2.6 The activities and responsibilities involved in the course of the project include:

Activity/ responsibility	**TERI**	**FAM**	**IIT**
Characterisation of soil and fly ash at site	√		
Selection, production and preparation of plant material	√		
Digging of pits	√		√
Application of mycorrhizae and organic compost	√		
Planting of tree species with appropriate quantities of fly ash, mycorrhizae, and organic compost	√		√
Maintenance of plantation	√	√	√
Study the improvement profile of plant species for survival and growth	√		√
Mobilisation of materials	√		√
Review, monitoring the progress	√	√	√

2.7 Work plan

Work plan (agency)	1st year			
	Quarter			
	1	2	3	4
Pre-plantation phase				
Soil collection at the and analysis of soil fly ash, organic compost (TERI)	√			
Plot-trial phase				
Selection of plant species (TERI, IIT)	√			
Application of mycorrhiza inoculum, fly ash and organic compost (FYM) before transplantation at site (TERI, IIT)	√			
Post-microplot plantation phase				
Studying the improvement profile in plant species(survival and growth) (TERI)		√	√	√
Plantation monitoring (TERI)		√	√	√
Demonstration of results, report preparation, etc.				√

2.8 List of trees planted

- *Ceiba pentandra*
- *Melia azadirach*
- *Cassia siamea*
- *Erythrina indica*
- *Cassia glauca*
- *Bauhinia purpurea*
- *Putranjiva*
- *Pongamia glabra*
- *Thevetia elifera*
- *Delonix regia*

PART-III

3.0 Implementation

Analysis of fly ash

The fly ash used was analyzed for the following physio-chemical parameters

- pH and electrical conductivity
- Available phosphorus and potassium
- Organic carbon and total nitrogen
- Total and available zinc, manganese, iron and copper
- Total concentration of cadmium, cobalt, lead, nickel, chromium etc.,

3.1 Treatments

The nutrient profile of the soil from all the four sites, the soil showed a deficiency of the major nutrients (Table 2a). Fly ash was used as a supplement/enricher for phosphorus and potassium; FYM (Table 2a) was used to supply organic carbon and nitrogen and also to improve the physical properties of the soil. Mycorrhiza was used as a biofertilizer in order to increase the availability of phosphorus in the fly ash-amended soil.

(a) Mycorrhizal consortium : Mycorrhizal consortium @ 600 propagules/pit^{-1}

(b) FYM : Fly ash mix : 3 : 1 (v/v) in soil

Treatment combinations :

A : FYM + Fly ash + Mycorrhiza
B : FYM + Fly ash - Mycorrhiza
C : FYM + Mycorrhiza
D : FYM (IIT, Delhi) - Mycorrhiza

Location of the plantation sites

Site	Location
I	Near Nalanda Guest House (Annexure 1)
II	Near Swimming Pool (Annexure 2)
III	Near Vaishali Apartments (Annexure 3)
IV	Fenced Field Site (Opp. Vaishali Apts.) (Annexure 4)

All the sites were located in a semi arid zone, at IIT, New Delhi, at 255 m above mean sea level. The sites are not under any cropping pattern and productive use.

The soil type at all the sites is sandy loam (0-30 cm depth), Hypothermic Typic Haplustalf, and deficient in nutrients, particularly phosphorus. The sites were sparsely covered by annual weeds and plantations. Site IV had having major problems with termite infestation and irrigation. The other three sites were having problem of human intervention and termite problem as well.

3.2 Raising of plantlets

The seeds of plant species raised at the TERI nursery were obtained from phenotypically superior (elite) trees.

To prepare the growth substrate, pure sand and FYM were thoroughly mixed in a 3:1 ratio. Polybags of 2 kg capacity were filled with this mix and stacked in the nursery. Two seeds of a species were sown in each polybag. One seedling was maintained after germination. The bags were watered and weeded regularly.

3.3 Selection of tree species

The following tree species were selected on the basis of their suitability to the site, edapho-climatic conditions, growth habits and economic importance. *Ceiba pentandra* showed high mortality and was replaced by *Delonix regia* in August 1998.

Table 1

Tree species	Spp. #	Code	Source
Ceiba pentandra	**1**	CP	TERI
Melia azadirach	**2**	MA	-do-
Cassia siamea	**3**	CS	-do-
Erythrina indica	**4**	EI	-do-
Cassia glauca	**5**	CG	-do-
Bauhinia purpurea	**6**	BP	-do-
Putranjiva	**7a**	PJ	IIT, Delhi
Pongamia glabra	**7b**	PG	-do-
Thevetia elifera	**8**	TE	TERI

3.4 Transplantation

Plantation was carried out in already-existing pits at the four sites on the IIT Delhi campus in September 1997. Most of the plantation work at the fourth site was carried out by the Horticultural Department, IIT. Appropriate doses of mycorrhizal inoculum, fly ash, and FYM were applied according to the treatment to the pits before transplantation

3.5 Soil sampling and analysis

Sampling

Prior to plantation soil samples were collected from all the four sites. The pipe and hammer technique was used to collect samples at a depth of 30 cm. Ten such samples were piped out at random from different locations and a composite sample was retrieved after homogenization. This sample was used for chemical analysis.

Processing of soil samples

Soil samples were air-dried at 20-25°C. Large lumps of moist soil were broken by hand and spread on paper in a room free of fumes, dust etc. Coarse concretions, stones and pieces of macro-organic matter (root, leaves and other vegetative materials) were picked out. After air-drying, the samples were passed through a 2-mm sieve and were processed for the soil chemical analysis.

Parameters analysed

The samples were analysed for the following parameters:

Soil chemical parameters (Table 2a):

- Soil pH and electrical conductivity
- Available phosphorus and potassium
- Organic carbon and total nitrogen

Physical parameters (Table 2b)

- Bulk density
- Particle density
- Porosity
- Permeability
- Soil texture

3.6 Methods

Parameter	Reference of methodology
pH and EC	(International Society of Soil Science, 1930)
Available phosphorus	Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with Sodium bicarbonate. Circular 939 US Department of Agriculture, Washington, DC.
Available potassium	Wood, L.K and DeTurk, E.E. 1940. The adsorption of potassium in soils in replaceable form. Soil. Sci. Soc. Am. Proc. 5: 152-161
Total nitrogen	Bremner, 1960. Determination of nitrogen in soil by Kjeldahl method. J. Agric. Sci. 55:11-13.
Organic carbon	Datta, N.P., Khera, M.S. and Saini, T.R. 1962. A rapid calorimetric procedure for the determination of the organic carbon in soils. J. Indian Soc. Soil Sci. 10: 67-74.
Total Cr, Co, Cu, Fe, Mn, Zn, Pb, Ni, As, Se, Mo	Vogel, A..I. 1962. A text of quantitative inorganic analysis. 3rd edition, Longmans.
Available Cu, Fe, Mn, Zn	Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J. 42: 421-428
Radioactive K, Ra, Ac	Done at IOP, Bhubhaneshwar.
Dehydrogenases	*Cassida, L.E.,* 1977. Microbial metabolic activity in soil as measured by dehydrogenase determination. Applied Environment Microbiology. 34: 630-636
Total microbial count	Clark, F.E. 1965a. Agar-plate method for total microbial count. Pages 1460-1466 in C.A. Black et al., Eds. Methods of soil analysis Part 2. Agronomy No. 9. American Society of Agronomy, Madison, WI.
Total n2-fixing microrganisms	Somasegaran, P and Hoben, H.J. 1985. Methods in Legume – Rhizobium technology. NifTAL, University of Hawaii, Honolulu
Total phosphorus-solubilizing microrganisms	Pikovskaya, R. I. 1948. Mobilization of phosphorus in soil in connection with vital activity of some microbial species. *Mikrobiologiya* 2000. 17: 362-370
Mycorrhizal propagule density	Tennant, D. 1975. A test of modified line intersects method of estimating root length. *J Eco.* 63: 995-1001 Gaur, A., Adholeya, A. and Mukerji, K.G. 1998. A comparison of AM fungi inoculants using *Capsicum* and *Polianthes* in marginal soil amended with organic matter. Mycorrhiza 7: 307-312.

4.0 Mycorrhizal inoculation

Preparation of arbuscular mycorrhiza (AM) inoculum and infectivity bioassay

The mixed indigenous AM fungal inoculum containing native propagules of *Glomus, Gigaspora,* and *Scutellospora* spp. was obtained by isolating the propagules (Gerdemann and Nicolson, 1963) from the wasteland site. The crude inoculum (spores/sporocarps, hyphae, and root bits) with sterilized soil of the same site (solarized at 56° ± 3°C for eight days by covering with white translucent polyethylene sheet). *Sorghum vulgare.* L was grown continuously for two cycles (each cycle 16 weeks) in a green house at 32° ± 5°C, after which the shoots of the plants were removed. The soil and roots left in the pots were dried in shade for three weeks. The air-dried mass from all the pots was homogenized thoroughly (the roots were cut into smaller pieces before mixing). The inoculum at each harvest was subjected to a bioassay to assess the number of infectious propagules. Inoculum potential was expressed as the number of propagules per gram of substrate using a bioassay (Gaur et al. 1998) with sorghum. The inoculum was distributed in a series of plastic pots (7 cm height and 5 cm diameter) containing 100 g of inoculum in each pot. A pot containing unsterilized soil alone was also maintained to determine the background level of infectious propagules present in the soil. Seeds of sorghum (*Sorghum vulgare* L.) were graded by weight (0.03 g – 0.04 g) and surface sterilized with 10% H_2O_2 for five minutes. Subsequently, the seeds were washed repeatedly with sterile water and kept for germination on moist cotton layers in petriplates at 30°C for 48 hours. Eight seedlings were placed in each pot and maintained in a greenhouse at 35° ± 5°C with 60% relative humidity. The pots were watered at regular intervals so as to maintain the soil moisture content (gravimetrically) at approximately 60% of the water holding capacity and harvested after 14 days.

5.0 Assessment of primary entry points/infectious propagules

At harvest, the shoots were cut and the root system with intact soil was dipped in 500 mL Calgon (sodium hexametaphosphate, 2%) solution. After 8 hours the soil was gently dispersed and Calgon solution was drained out. It was then replaced with fresh water. This was repeated 3-4 times till the roots became clear and little debris was seen attached to the roots. The roots were then stained as described by Phillips and Hayman (1970).

To analyze the random distribution of infection units, the root length was determined by spreading the complete root system in a gridded (2 x 2 cm) petriplate. The number of intersects across the gridlines was counted and the root length was calculated according to Tennant's method (1975), i.e.,

Root length = Number of intersects x 11/14 x grid size

The roots were then chopped into 1 cm pieces and 50 root bits per replicate were selected randomly and mounted on glass slides with a drop lactoglycerol and observed at a magnification of 20X under a compound microscope (Gallen III, Leica, Cambridge, UK) attached to a CCD camera and an image analyser system (Leica, Switzerland) controlled by Quantimet 500 option. The total number of entry points in these pieces was counted and the number of entry points formed per cm root length was assessed.

Multiplying this value by the root length, the total number of entry points formed in the whole root system was calculated.

Six hundred infectious propagules were inoculated for each plant species at transplantation.

RESULTS AND DISCUSSIONS

Results of chemical analysis

Table 2a Chemical and nutritional analysis of soil and farm yard manure

Analysis	Parameters	Results				
			Soil			
		FYM	Site I	Site II	Site III	Site IV
Chemical	pH (1:2.5; H_2O)	7.15	7.66	7.65	7.74	7.76
	Electrical conductivity (dS/m)	1.75	0.204	0.205	0.172	0.207
	Total N (%)	1.2	0.0084	0.0084	0.0042	0.0042
	Available phosphorus (ppm)	30.9	0.42	0.14	3.94	8.27
	Available Potassium (ppm)	183.67	16	17	56	58
	Organic carbon (%)	4.5	0.42	0.38	0.21	0.19

Chemical profile of the plantation sites:

The chemical profile in terms of pH and total soluble salts (EC) was found to be similar in all the four sites. Soil at all the four sites was found to be deficient in the major nutrients, but their level varied among the sites. Sites III and IV (0.0042%) were more deficient in nitrogen than sites I and II (0.0084%). Sites I and II showed a low profile for phosphorus (0.42 and 0.14 ppm, respectively) and potassium (16 and 17 ppm, respectively) as compared to sites III and IV. The highest phosphorus concentration (8.27 ppm) was analyzed in samples collected from site IV. Organic carbon showed a similar trend as nitrogen with sites I and II (0.42 and 0.38%, respectively) having a higher organic carbon content as compared to sites III and IV (0.21 and 0.19%, respectively).

Table 2b Analysis of fly ash for chemical, physical, nutritional and heavy metals

Analysis	Parameter	Results
		Fly ash
Chemical	pH (1:2.5; H_2O)	6.56
	Electrical conductivity (dS/m)	1.13
	Total N (%)	0.011
	Available phosphorus (ppm)	11.68
	Available Potassium (ppm)	111.85
	Organic carbon	0.60
Physical	Bulk density (g/cc)	0.762
	Particle density(g/cc)	1.89
	Porosity (%)	59.6
	Permeability (cm/s)	5.86 x 10^{-5}
	Particle site distribution	
	Sand: Medium (%)	3.70
	Coarse (%)	0.20
	Fine (%)	28.70
	Silt (%)	63.96
	Clay (%)	3.50
Heavy Metals (ppm)	Cadmium	0.843
	Chromium	22.81
	Cobalt	27.86
	Copper (total)	12.10
	Copper (available)	0.19
	Iron (total)	10562.50
	Iron (available)	2.22
	Lead	89.26
	Manganese (total)	152.24
	Manganese (available)	0.36
	Nickel	66.63
	Zinc (total)	60.69
	Zinc (available)	0.41

The chemical profile of fly ash

Major nutrient data presented in 1(b) indicated that among all major nutrients phosphorus was higher when compared to its average concentration in soils. Fly ash has a high porosity (59.6%). The concentration of various heavy elements in the fly ash is given in 1(b).

4.0 Results and discussions

4.1 Survival and height of tree species

Survival of the tree species and their growth was recorded regularly after every quarter and needful beating up operations followed when required.

4.1.1 Survival data

I. Survival rate of the plants was recorded and beating up operations were undertaken in November 1997. Out of the 8 tree species planted, *Melia azadirach, Erythrina indica, Bauhinia purpurea, Pongamia glabra, and Thevetia elifera* showed 100% survival at all the three sites. *Cieba pentandra* showed higher survival rate at site I (100%) followed by site III (92 %), and site II (89%). The rate of survival of *Cassia siamaea* was highest at site II (89%) followed by at site III (75%), and site I (67%). *Cassia glauca* showed the lowest survival rate with 58% at site III, 22% at site II. No plant survived at site I.

Table 3a Survival rate of the plants was recorded in November 1997

Plant Spp.	*November 1997*			
	Site I	**Site II**	**Site III**	**Site IV**
Ceiba pentandra	100	89	92	-
Melia azadirach	100	100	100	-
Cassia siamea	67	89	75	-
Erythrina indica	100	100	100	-
Cassia glauca	0	22	58	-
Bauhinia purpurea	100	100	100	-
Pongamia glabra	100	100	100	-
Thevetia elifera	100	100	100	-

Table 3b Survival rate of the plants recorded in the months of February and March 98

Plant species	FEBRUARY RECORD (survival %)			MARCH RECORD (survival %)		
	Site I	Site II	Site III	Site I	Site II	Site III
Ceiba pentandra	16.66	33.33	83.33	16.66	22.22	58.33
Melia azadirach	100	88.88	100	100	88.88	100
Cassia siamea	66.66	44.44	83.33	50	11.11	83.33
Erythrina indica	83.33	77.77	91.66	33.33	55.55	75
Cassia glauca	100	88.88	75	100	77.77	75
Bauhinia purpurea	100	66.66	100	100	55.55	83.33
Pongamia glabra	83.33	100	-	83.33	100	-
Putranjiva	-	-	91.66	-	-	83.33
Thevetia elifera	100	100	100	100	66.66	100

- *Putranjiva* not included in first and second site

The survival rate decreased at all the three sites (from February 1998 to March 1998) for most of the tree species due to poor maintenance.

SITE IV - The survival rate of the plants was 97% in February, which was reduced to 90% in March, mainly due to poor maintenance.

Table 3c Survival rate of the plants recorded in May 1998 shows a further decrease in the survival rates

Plant species	SURVIVAL %		
	Site I	Site II	Site III
Ceiba pentandra	0	0	25
Melia azadirach	83.33	88.88	100
Cassia siamea	66.66	22.22	75
Erythrina indica	33.33	44.44	33.33
Cassia glauca	83.33	22.22	33.33
Bauhinia purpurea	100	44.44	91.66
Pongamia glabra	66.66	100	-
Thevetia elifera	100	77.77	100

- *Putranjiva* not included in first and second site

SITE IV - The survival rate of the plants was 59.4% in May 1998 mainly due to poor maintenance.

Table 4 Height of the plants was taken as a measure of their growth in the first quarter (Nov. 1997 to Jan. 1998) at the three sites at IIT

	Height (in m)																					
Species	***Ceiba pentandra***			***Melia azadirach***			***Cassia siamea***			***Erythrina indica***			***Cassia glauca***			***Bauhinia purpurea***			***Pongamia glabra***		***PJ***	***Thevetia elifera***		
Treatment	Site #			Site #			Site #			Site #			Site #			Site #			Site #		#	Site #		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
A	1.4	1.7	1.7	1.5	1.5	1.7	1.7	1.5	1.7	1.7	1.8	1.4	1.8	1.8	1.4	1.7	1.8	1.4	0.4	0.35	0.55	1.2	1	1.2
B	1.6	1.7	1.6	1.6	1.6	1.7	1.6	1.5	1.8	1.3	1.6	1.7	1.5	1.6	1.7	1.8	1.3	1.6	0.39	0.45	0.5	1.5	1.6	0.9
C	1.5	1.7	1.8	1.5	1.7	1.6	1.5	1.4	1.5	1.5	1.9	1.5	1.6	1.6	1.7	1.5	1.5	1.6	0.42	0.75	0.5	1.4	1.2	1.3
D	*	1.5	1.3	*	1.6	1.5	*	1.5	1.3	*	1.7	.85	*	1.4	*	*	1.7	1.9	*	0.55	0.52	*	1.3	1.1

* treatment not included due to limited number of pits on the site

PJ - Putranjiva

Where,

A : FYM + Fly ash + Mycorrhiza
B : FYM + Fly ash – Mycorrhiza
C : FYM + Mycorrhiza
D : FYM (IIT, New Delhi)- Mycorrhiza

Table 5 Height of the plant was taken as a measure of its growth in the second quarter (Feb-April 1998) at the three sites.

Height (m)																											
Species	***Ceiba pentandra***			***Melia azadirach***			***Cassia siamea***			***Erythrina indica***			***Cassia glauca***			***Bauhinia purpurea***			***Pongamia glabra***		***PJ***	***Thevetia elifera***		
Treatment	Site #			Site #			Site #			Site #			Site #			Site #			Site #		#	Site #		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
A	-	-	1.72	1.5	1.45	0.82	0.4	0.2	1.25	0.6	0.7	1.33	1.78	1.62	1.75	1.75	1.1	1.3	0.36	0.42	0.55	1.2	-	1
B	-	-	1.62	1.52	1.25	1.82	1.5	0.15	1.6	-	1	1.65	1.5	-	1.27	1.77	0.8	1.25	0.42	0.35	0.42	1.42	0.52	0.9
C	1.5	0.3	1.65	1.6	1.5	1.55	1.7	0.55	1.45	0.55	1.6	1.45	1.6	1.52	1.37	1.4	1.45	1.27	0.45	0.6	0.45	1.52	0.47	1.28
D	*	1.7	-	*	1.53	1.23	*	1	1.05	*	1.72	0.9	*	1.13	-	*	1.67	1.525	*	0.52	0.53	*	1.29	0.95

* Treatment not included due to limited number of pits on the site
 All the replicates are dead
Most of the surviving plants had broken top shoots, which affected the average height of the plants.

Where,
A : FYM + Fly ash + Mycorrhiza
B : FYM + Fly ash – Mycorrhiza
C : FYM + Mycorrhiza
D : FYM (IIT, New Delhi)- Mycorrhiza

Table 6 Height of the plants was taken as a measure of their growth in September 1998 at the three sites. Due to the beating up operations carried out in August 1998 the height of the replicates within a treatment is not comparable.

	Height (m)																										
Species	*Delonix regia*			*Melia azadirach*			*Cassia siamea*			*Erythrina indica*			*Cassia glauca*			*Bauhinia purpurea*			*Pongamia glabra*		*PJ*	*Thevetia elifera*		
Treatments	Site #			Site #			Site #			Site #			Site #			Site #			Site #		#	Site #		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
A	1.35	1.1	1.6	2.52	4.12	1.57	1.5	1.35	2.33	1.65	1.27	1.6	1.9	1.55	1.55	1.8	1.4	1.43	0.75	0.9	0.53	2.25	1.4	1.03
B	0.6	1.75	1.23	1.8	2.87	2.13	1.65	1.15	1.98	1.25	1.25	1.25	1.5	1.55	1.68	2.65	1.1	1.23	0.75	1	0.85	2.6	1.67	1.1
C	1.25	2.02	1.16	2.15	3.65	2.16	1.7	1.5	1.53	1.55	1.1	1.33	1.75	1.27	1.3	2.4	1.8	1.6	0.7	1.6	0.48	2.15	1.55	1.72
D	*	1.66	1.33	*	2.66	1.56	*	1.62	1.36	*	1.6	1.3	*	1.5	0.96	*	1.5	1.75	*	0.86	0.46	*	2.06	1.5

* treatment not included due to limited number of pits on the site

Most of the surviving plants had broken top shoots which affected the average height of the plants.

Where,

A : FYM + Fly ash + Mycorrhiza
B : FYM + Fly ash – Mycorrhiza
C : FYM + Mycorrhiza
D : FYM (IIT, New Delhi)- Mycorrhiza

PART IV

5.0 Conclusion

The project was undertaken to demonstrate how problematic sites with many stress characteristics such as termite infestations can be dealt with and reclaimed with fly ash interventions and utilization of biological inputs along with it.

The project activity at the initial stage focussed on setting up a system of soil management and capacity-building at the implementing site, at IIT. All the inputs including indigenous soils were analyzed and properties were characterized. Simultaneously, selection of tree species based on earlier experiences and mycorrhiza was made. The plantations underwent adverse conditions, such as moisture stress, termite infestation, soil erosion, and human intervention. The above factors caused high mortalities at different sites. This was suitably addressed by amending management practices, protecting the plants and better monitoring. Subsequently a higher survival rate was achieved. The growth of plants and soil properties proves that the sites are now on the way to reclamation. The regular monitoring by FAM, maintenance by IIT and recording of annual data by TERI will demonstrate the level of success over the next 6-7 years. The progress and plant are comparable to those cultivated conventionally which is most satisfying.

PART V

6.0 Suggested Future Plan of Action

Maintenance plan for regular monitoring and upkeep of all the four sites has been evolved and described to IIT staff who is associated with the project. The details of such plans are enclosed herewith. This would enable plantation to undergo normal practices of management and trouble-free environment of growth. It is required that annual growth data be collected by TERI for this project in order to compile the information for drawing meaningful conclusion.

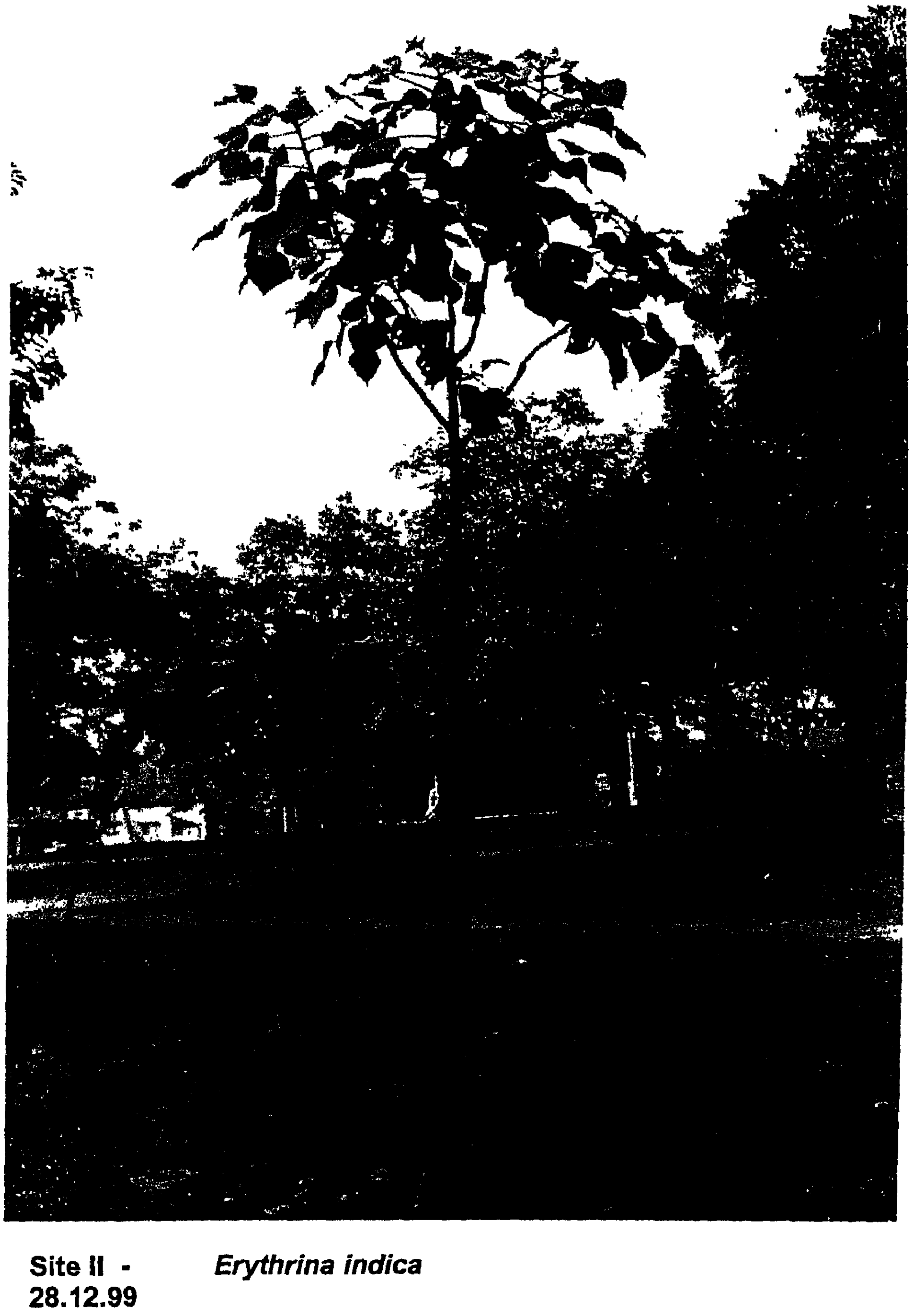
PART VI

7.0 Photographs

Site I - *Cassia glauca*
28.12.99
Plantation August 1998

Site I - ***Cassia siamea Tree***
28.12.99
Plantation August - September 1997

Site III - ***Cassia siamea***
28.12.99
Plantation August - September 1997



Site II - ***Erythrina indica***
28.12.99
Plantation August - September 1997

Site III - ***Melia***
28.12.99
Plantation August - September1997

PART VII

8.0 References

Biermann B J and Linderman, R G 1981

Quantifying vesicular-arbuscular mycorrhizae: a proposed method towards standardization

New Phytologist **87**: 63-67

Bremner J M 1960

Determination of nitrogen in soil by Kjeldahl method

Journal of Agricultural Science **55**: 11-13

Cassida LE. 1977

Microbial metabolic activity in soil as measured by dehydrogenase determination

Applied Environment Microbiology **34**: 630-636

Clark F E. 1965a

Agar-plate method for total microbial count *Methods of soil analysis Part 2 Agronomy Number 9,* pp. 1460-1466, edited by C A Black et al. Madison, Wisconsin, USA: American Society of Agronomy, Madison, WI

Datta N P, Khera M S, and Saini T R. 1962

A rapid calorimetric procedure for the determination of the organic carbon in soils

Journal Indian Soc. Soil Sci. **10**: 67-74

Gaur A, Adholeya A, and Mukerji K G. 1998

A comparison of AM fungi inoculants using Capsicum and Polianthes in marginal soil amended with organic matter

Mycorrhiza **7**: 307-312

Gerdemann J W and Nicolson T H. 1963

Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting

Transactions of the British Mycological Society **46**: 235-244

Hoagland D R and Arnon D I. 1938

The water culture method of growing plants without soil

Berkeley, California: California Agricultural Experiment Stations. [Circular 347]

Kitson R E and Mellon MG. 1944

Colorimetric determination of phosphorus as molybdivanado phosphoric acid

Ind. Eng. Chem. Anal. **Edition 16**: 379-383

Lindsay W L and Norvell W A. 1978

Development of a DTPA soil test for zinc, iron, manganese and copper

Soil Sci. Soc. Am. J. **42**: 421-428

Olsen S R, Cole C V, Watanabe F S, and Dean L A. 1954

Estimation of available phosphorus in soils by extraction with sodium bicarbonate

Washington, DC: US Department of Agriculture. [Circular 939]

Phillips J M and Hayman D S. 1970

Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection

Transactions of the British Mycological Society **55**: 158-161

SAS Institute Inc. 1991 SAS/STAT User's Guide, release 6.03. SAS Institute Inc., Cary, N.C.

Tennant D,1975.

A test of modified line intersect method of estimating root
J. Ecology **63: 995-1001**

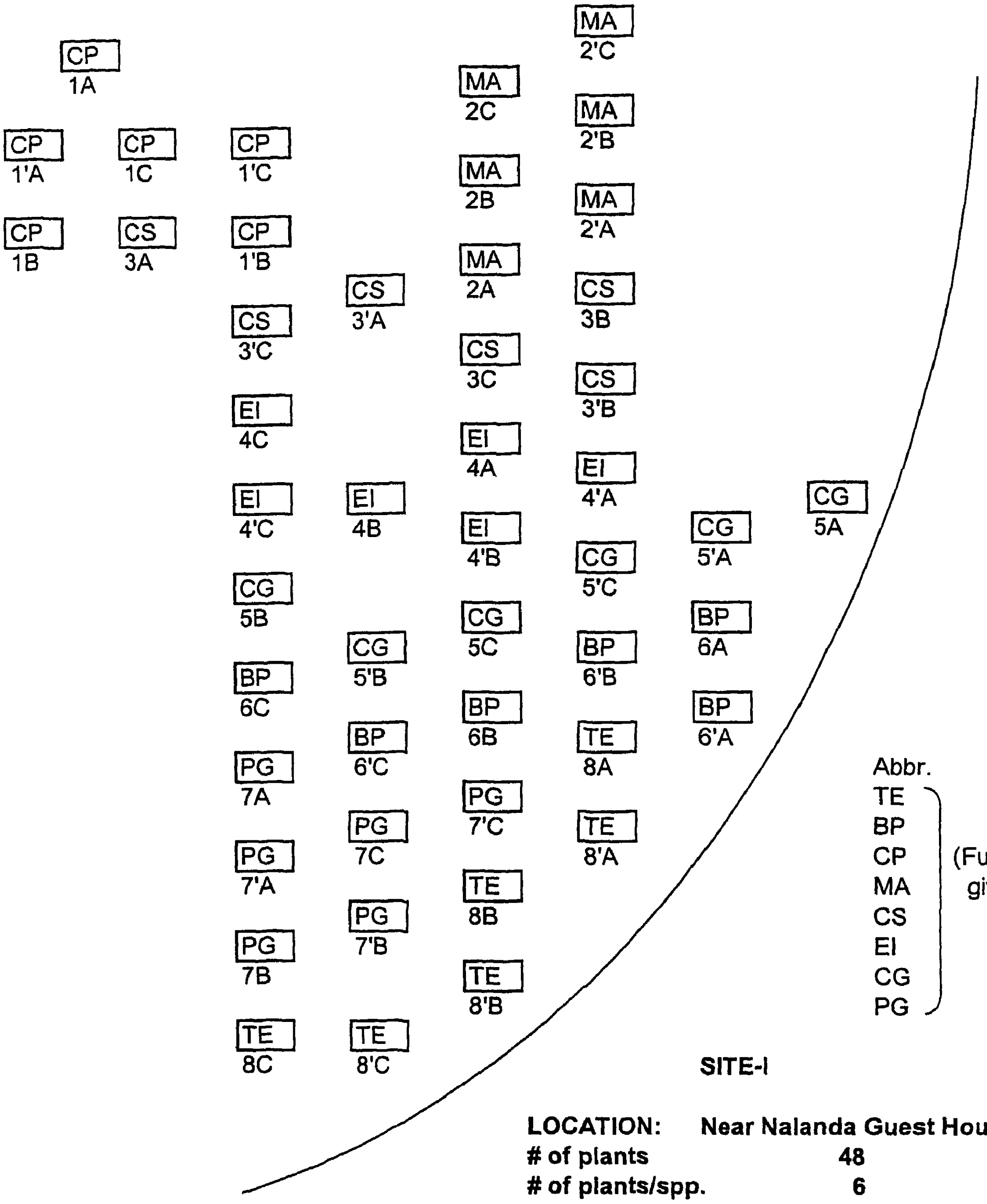
PART VIII

Glossary/Abbreviations/Units

A	Fly ash
YM	Farmyard manure
AM	Fly ash mission
pm	parts per million
S	deci seimen
g	microgram
P	inoculum potential
AM	Vesicular arbuscular mycorrhiza
M	Arbuscular mycorrhiza
PF	Tri-phenyl formazan
BD	Randomised block design
RD	Completely randomised design
fu	Colony forming units
SD	Least significant difference
D	Dose
a,b,c,d	*means followed by same letter did not differ significantly by DMRT (P=0.05)
Spp.	Species
CP	*Ceiba pentandra*
BP	*Bauhinia purpurea*
MA	*Melia azadirach*
CS	*Cassia siamea*
PG	*Pongamia glabra*
EI	*Erythrina indica*
TE	*Thevetia elifera*
CG	*Cassia glauca*
DR	*Delonix regia*
PJ	*Putranjiva*

Annexures

1 Site I
2 Site II
3 Site III
4 Site IV

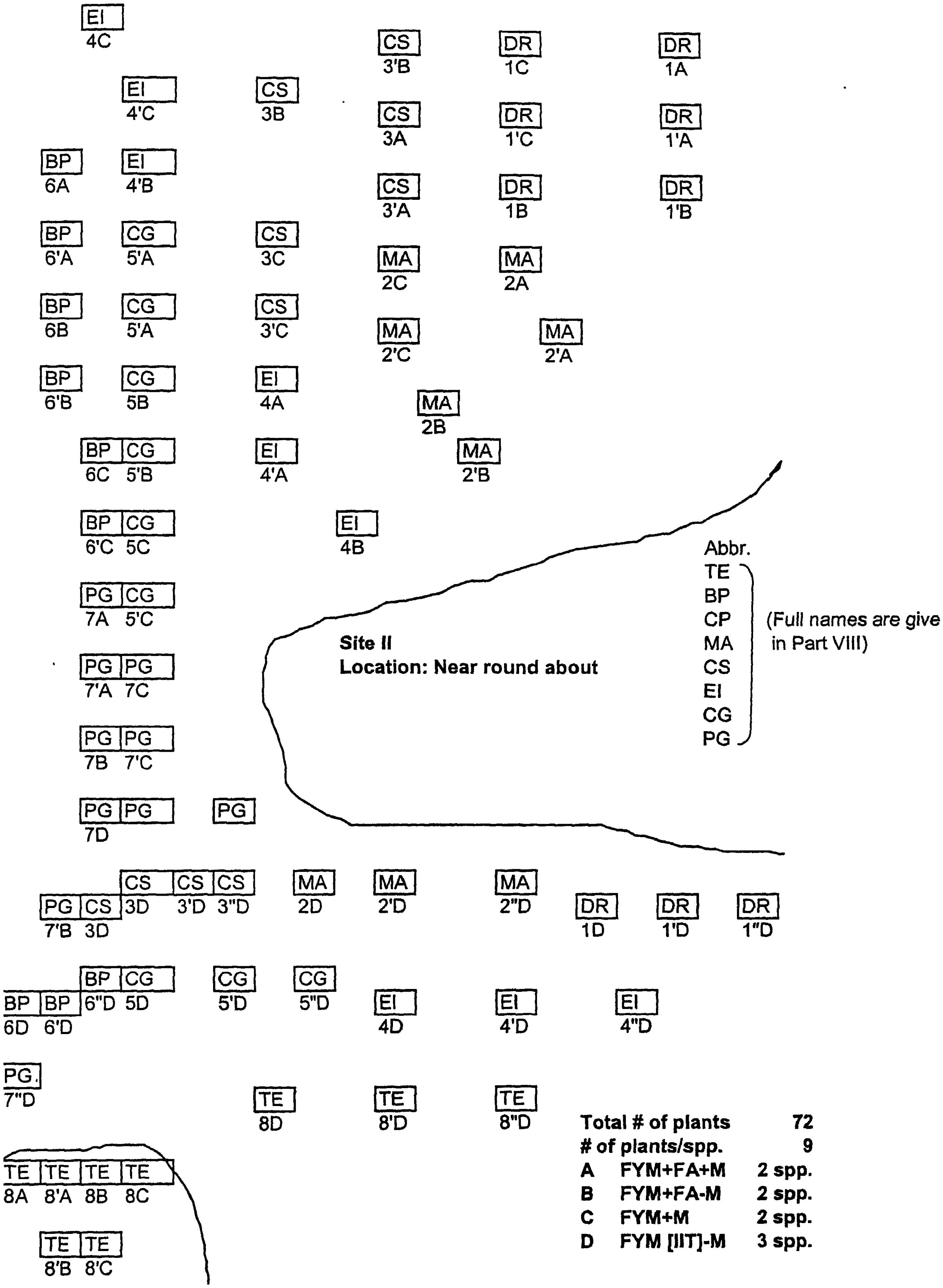


Abbr.
TE
BP
CP
MA
CS
EI
CG
PG
(Full names are given in Part VIII)

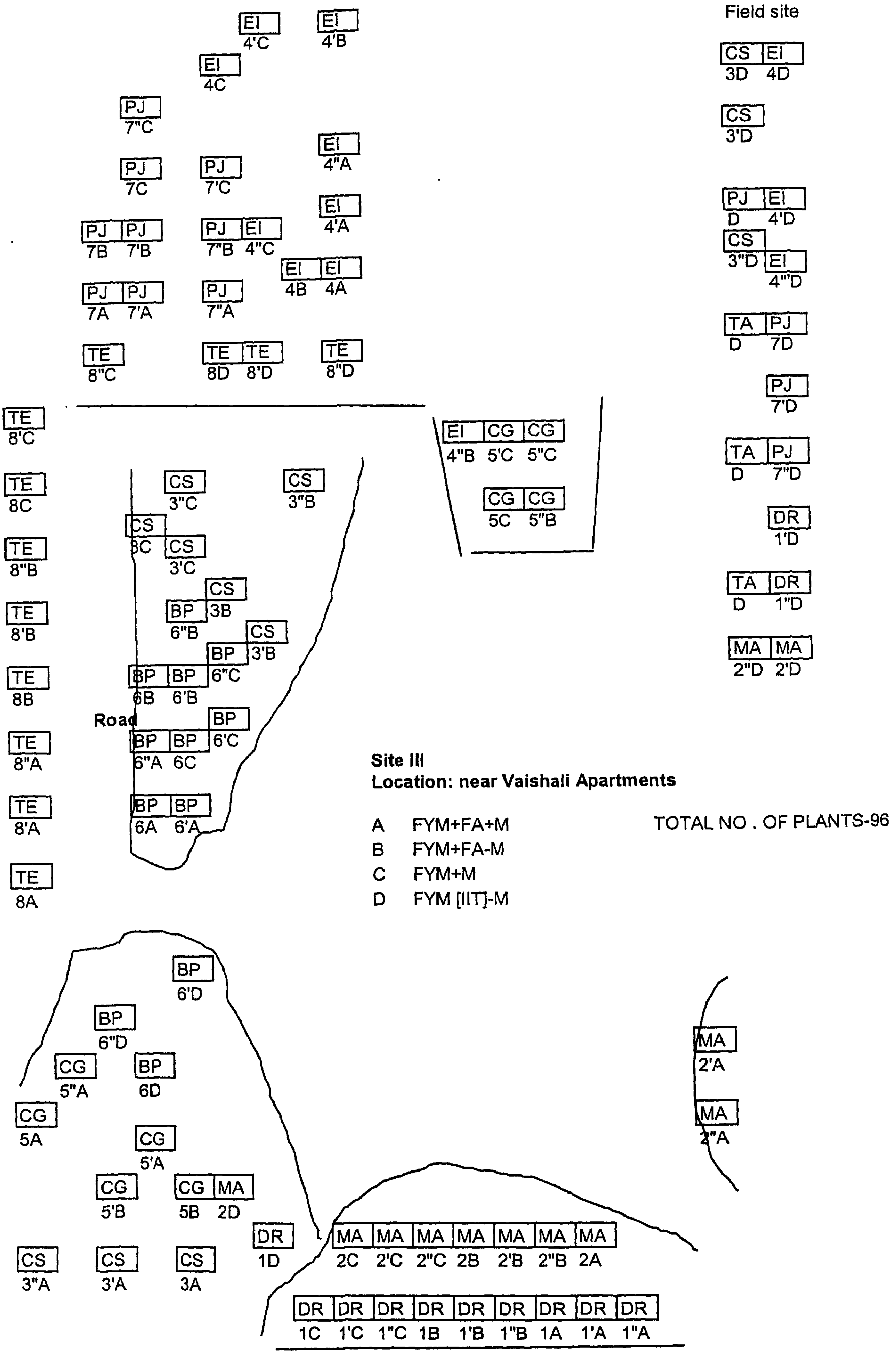
SITE-I

LOCATION: Near Nalanda Guest House
# of plants 48
# of plants/spp. 6

Treatments		**Plants**
A	**FYM+FA+M**	**2/spp.**
B	**FYM+FA-M**	**2/spp.**
C	**FYM+M**	**2/spp.**
D	**FYM (IIT)-M**	**0**



Total # of plants		**72**
# of plants/spp.		**9**
A	**FYM+FA+M**	**2 spp.**
B	**FYM+FA-M**	**2 spp.**
C	**FYM+M**	**2 spp.**
D	**FYM [IIT]-M**	**3 spp.**

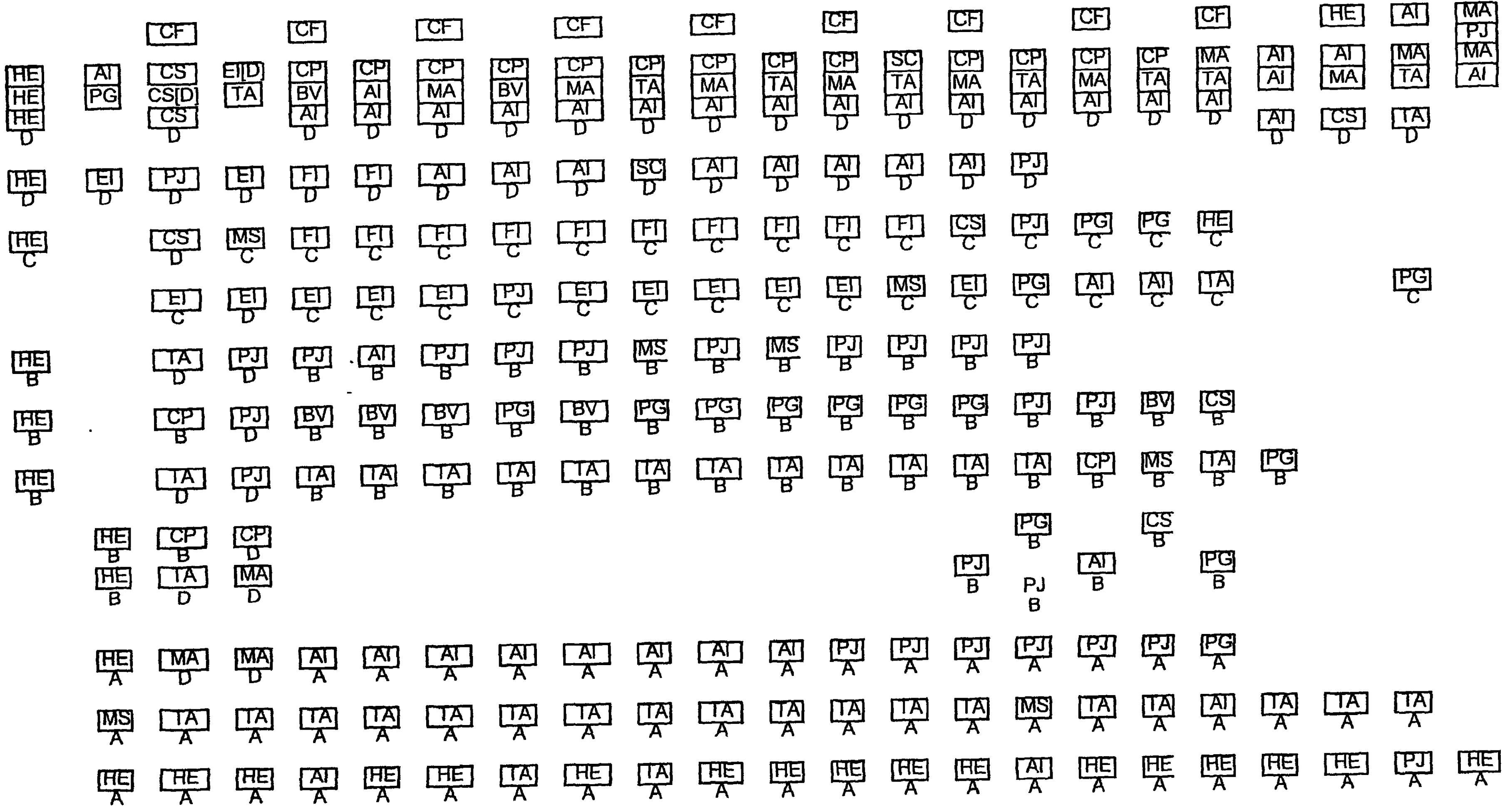


Site III
Location: near Vaishali Apartments

A	FYM+FA+M
B	FYM+FA-M
C	FYM+M
D	FYM [IIT]-M

TOTAL NO . OF PLANTS-96

Site IV -Open field near Vaishali apartments


CF CF CF CF CF CF CF CF CF HE AI
MA PJ MA AI
HE HE HE D
AI PG
CS CS[D] CS D
EI[D] TA
CP BV AI D
CP AI AI D
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CP BV AI D
CP MA AI D
CP TA AI D
CP MA AI D
CP TA AI D
CP MA AI D
SC TA AI D
CP MA AI D
CP TA AI D
CP MA AI D
CP TA AI D
MA TA AI D
AI AI
AI D
AI MA
CS D
MA TA
TA D
HE D, EI D, PJ D, EI D, FI D, FI D, AI D, AI D, AI D, SC D, AI D, AI D, AI D, AI D, AI D, PJ D
HE C, CS D, MS C, FI C, FI C, FI C, FI C, FI C, FI C, FI C, FI C, FI C, FI C, CS C, PJ C, PG C, PG C, HE C
EI C, EI D, EI C, EI C, EI C, PJ C, EI C, EI C, EI C, EI C, EI C, MS C, EI C, PG C, AI C, AI C, TA C, PG C
HE B, TA D, PJ D, PJ B, AI B, PJ B, PJ B, PJ B, MS B, PJ B, MS B, PJ B, PJ B, PJ B, PJ B
HE B, CP B, PJ D, BV B, BV B, BV B, PG B, BV B, PG B, PG B, PG B, PG B, PG B, PG B, PJ B, PJ B, BV B, CS B
HE B, TA D, PJ D, TA B, TA B, TA B, TA B, TA B, TA B, TA B, TA B, TA B, TA B, TA B, TA B, CP B, MS B, TA B, PG B
HE B, CP B, CP D, PG B, CS B
HE B, TA D, MA D, PJ B, PJ B, AI B, PG B
HE A, MA D, MA D, AI A, AI A, AI A, AI A, AI A, AI A, AI A, AI A, PJ A, PJ A, PJ A, PJ A, PJ A, PJ A, PG A
MS A, TA A, TA A, TA A, TA A, TA A, TA A, TA A, TA A, TA A, TA A, TA A, TA A, TA A, MS A, TA A, TA A, AI A, TA A, TA A, TA A
HE A, HE A, HE A, AI A, HE A, HE A, TA A, HE A, TA A, HE A, HE A, HE A, HE A, HE A, AI A, HE A, HE A, HE A, HE A, HE A, PJ A, HE A

A	FYM + FA + M
B	FYM + FA - M
C	FYM + M
D	FYM (IIT) - M